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Peer Review of Capture Zone Analysis
Former Boeing C-6 Facility
Los Angeles, California

Avocet Environmental, Inc. (Avocet) is pleased to present this summary of its peer review of a Technical Memorandum entitled *Capture Zone Analysis in the B-Sand and C-Sand, Former Boeing C-6 Facility, Los Angeles, California* (Technical Memorandum), prepared by Rubicon Engineering (Rubicon) and dated April 21, 2006. The objective of Rubicon's analysis was "...to determine the placement for proposed ground water extraction wells at the site for hydraulic control of chemical constituents in groundwater beneath the site." Rubicon utilized "representative" aquifer hydraulic parameters derived from existing site characterization documents and a well-established groundwater semi-analytical model to accomplish their objective. The purpose of this document is to review Rubicon's analysis and provide comments on model and input parameter selection and wellfield design.

HYDROGEOLOGIC SETTING

More than 60 years of industrial use has resulted in impacts to both soil and groundwater underlying the Former Boeing C-6 Facility. Whereas vadose zone impacts have been or are being addressed, alternatives to address impacts of halogenated solvents on the saturated zone are still being evaluated. The principal hydrogeologic unit underlying the site is the Lakewood Formation (Haley & Aldrich, 2002). The primary (shallow) water-bearing unit within the Lakewood Formation is the Middle Bellflower Sand, which is subdivided into the B-Sand (Upper and Lower) and C-Sand. Rubicon performed separate capture zone simulations for the B- and C-Sands.

MODEL SELECTION

Rubicon utilized the analytical code RESSQ (Javandel et al., 1984) to model the capture zone created around a hypothetical pumping wellfield. RESSQ is a semi-analytical, two-dimensional solute transport model that calculates the streamline pattern in an aquifer. The model assumes a homogeneous, isotropic confined aquifer of uniform thickness, steady-state regional flow field, and advection and adsorption only (no dispersion or decay). RESSQ uses the same semi-analytical capture zone solution as EPA's Well Head Protection Area (WHPA) model and is, therefore, well

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documented and generally well accepted by the regulatory community for capture zone analysis. Since the site hydrogeology generally satisfies the model assumptions (e.g., homogeneous, confined aquifer of uniform thickness; steady-state, horizontal flow), the use of this code to model groundwater capture at the former Boeing C-6 Facility is considered appropriate.

SELECTION OF INPUT PARAMETERS

The model input parameters include: aquifer properties (hydraulic gradient, flow direction, aquifer thickness, hydraulic conductivity, and effective porosity) and well or wellfield parameters (number of wells and extraction rate per well). Rubicon derived the aquifer parameters from a review of available site characterization documents – including documents prepared for the adjacent Montrose Chemical and Del Amo Superfund Sites (CH2M Hill, 2004). The following table summarizes the input parameters used by Rubicon to model the B- and C-Sands beneath the former Boeing C-6 Facility.

Parameter	Rubicon Value	Units	Reference	Range	Reference
B-Sand					
Hydraulic gradient	0.001		Haley & Aldrich, 2004a	0.0006 to 0.0014	Haley & Aldrich, 2004b
Flow direction	South		Haley & Aldrich, 2004a	South	Haley & Aldrich, 2004a
Aquifer thickness	27.5	Feet	Haley & Aldrich, 2002	20 to 30	Haley & Aldrich, 2002
Hydraulic conductivity	20	Feet/Day	CH2M Hill, 2004	3.5 to 24	Haley & Aldrich, 2004b
Effective porosity	0.3		Assumed	0.3	Assumed
C-Sand					
Hydraulic gradient	0.001		March 2004 Water Levels	0.0004 to 0.0007	CH2M Hill, 2004
Flow direction	S17°W		Haley & Aldrich, 2004a	S17°W	Haley & Aldrich, 2004
Aquifer thickness	17	Feet	Haley & Aldrich, 2002	12 to 45	Haley & Aldrich, 2002
Hydraulic conductivity	145	Feet/Day	CH2M Hill, 2004	27 to 400	Haley & Aldrich, 2004b
Effective porosity	0.3		Assumed	0.3	Assumed

Rubicon's capture zone analyses were based on a single representative value selected from the literature. Avocet's review of available documents, however, indicates a substantial range in the hydraulic parameters (e.g., gradient, aquifer thickness, hydraulic conductivity) measured by various methods and researchers. These ranges are included in the table above. Comparison of the values used by Rubicon with the ranges reported in the literature reveals that Rubicon's values, while generally within the range, are frequently near one extreme of the range. While the hydraulic parameters selected may or may not be representative of the saturated zone, they reflect operator bias and introduce uncertainty into the model output. One method of addressing this type of uncertainty is sensitivity analysis. Sensitivity analysis is the process of varying model input parameters over a reasonable range (range of uncertainty in values of model parameters) and observing the relative change in model response. In this case, the aquifer and wellfield parameters could be varied over the ranges provided above and changes in the capture zone response noted. If it is determined that the capture zone is particularly sensitive to one or more parameters, additional

justification for the selected value(s) may be prudent. The sensitivity analysis would also provide insight into the degree of conservatism incorporated into the recommended wellfield design.

CAPTURE ZONE SIMULATIONS

Rubicon's B-Sand capture zone simulates eight extraction wells to control flow within the areas of groundwater impacted by trichloroethylene (TCE) at concentrations greater than 5,000 µg/L (source areas). Five wells are used to capture groundwater flow in the Building 2 source area and three wells are used to capture flow in the Lot 8 area. The simulated extraction rate for each of the eight wells is 3 gallons per minute (gpm). This extraction rate appears reasonable considering that the average B-Sand water injection rate achieved during recent bio-amendment pilot tests was 4.42 gpm (IRZ-Injection Table, Arcadis, 2005). Capture zone simulations are influenced by hydraulic conductivity (K), aquifer thickness (b), hydraulic gradient (i), and the extraction rate (Q). The maximum width (y_{max}) of the capture zone is directly proportional to the extraction rate (Q) and inversely proportional to the hydraulic conductivity (K), aquifer thickness (b), and hydraulic gradient (i).

$$y_{max} = \pm Q/(2Kbi)$$

Aquifer property values of K=20 ft/day, b=27.5 feet, i=0.001, and Q=577.5 ft^3/day (3 gpm) were used by Rubicon to model the saturated zone at the Former C-6 Facility. These values produced one- and five-year capture zone widths in the B-Sand of about 200 and 600 feet, respectively (note: the five-year simulation approximates y_{max}=525 feet). These values are consistent with capture zone theory, suggesting that the simulations are mathematically correct.

It is not clear from Rubicon's Technical Memorandum why they decided to employ three wells to establish hydraulic control over the Lot 8 source area and five wells to control flow in the Building 2 source area. Since both source areas (TCE>5,000 µg/L) cover approximately equal areas of equivalent aquifer, if three wells are sufficient in one area then three wells should suffice in both areas. It is possible that the difference reflects access limitations that Avocet is unaware of. Although Rubicon cites "potential" TCE mass removal rates on the order of 1.4 pounds per day, it is unlikely that the average TCE concentrations measured in monitoring wells (5,000 µg/L) will persist during extraction. More likely, dissolved TCE concentrations will rapidly fall during extraction, perhaps by one or two orders of magnitude, and contribution of groundwater extraction to TCE mass reduction will rapidly diminish. The more crucial role of groundwater extraction will likely be to inhibit contaminant migration while alternative methods (i.e., enhanced bioremediation) are used to remove TCE mass. Therefore, in the absence of outside limitations and recognizing the increased capital and operation and maintenance costs of additional wells, it is recommended that containment be established with as few wells as possible.

Although it may be addressed in other documents, Rubicon's Technical Memorandum does not provide any justification for limiting capture to TCE concentrations greater than 5,000 µg/L. If the objective is to limit migration of TCE to lower concentrations (i.e., 1,000 µg/L), as it was in the C-Sand, then the model should be reevaluated in light of that objective.

Rubicon's C-Sand capture zone simulation utilizes six extraction wells to control flow within the areas of groundwater impacted with TCE at concentrations greater than 1,000 µg/L (source areas). It is not clear why the target capture concentration is 1,000 µg/L in the C-Sand but 5,000 µg/L in the B-Sand. Three wells are proposed to capture groundwater flow in the Building 2 source area and three wells are recommended in the Lot 8 area. The simulated extraction rate for each of the six wells is 10 gpm. This extraction rate may be a little optimistic considering that the average measured on-site hydraulic conductivity in the C-Sand is only about twice that of the B-Sand (28 to 56 ft/day versus 11 to 28 ft/day; Haley & Aldrich, 2004b).

Aquifer property values of k=145 ft/day, b=17 feet, i=0.001, and Q=1,925.1 ft^3/day (10 gpm) were used by Rubicon to model the C-Sand saturated zone at the Former C-6 Facility. These values produced six-month, one-year, and two-year capture zone widths in the C-Sand of about 350, 550, and 900 feet, respectively (note: the two-year simulation approximates y_{max}). These values are consistent with capture zone theory, suggesting that the simulations are mathematically correct. However, the hydraulic conductivity used by Rubicon in the C-Sand analysis (145 ft/day) was derived from reports prepared by CH2M Hill for adjacent sites and is significantly greater than C-Sand hydraulic conductivity measurements reported for the subject site (28 to 56 ft/day; Haley & Aldrich, 2004b). The relevance of the C-Sand hydraulic conductivity value reported by CH2M Hill should be explored before the extraction wellfield design is finalized. It is recommended that a range of site-specific C-Sand hydraulic conductivity values be examined in a sensitivity analysis to ensure that containment is achieved under less optimistic aquifer conditions. The number of wells recommended by Rubicon appears sufficient to contain the generalized zones of TCE (>1,000 µg/L) impacted groundwater. However, the spacing of the wells in the southern (Lot 8) source zone could probably be increased with the southernmost well shifted farther south to improve containment of the leading plume edge.

Avocet appreciates the opportunity to be of service to BRC on this interesting project. If you have any questions, please do not hesitate to call.

Respectfully submitted,

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